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PACIFIC GAS AND ELECTRIC COMPANY
DEPARTMENT OF ENGINEERING RESEARCH

STATIC AND DYNAMIC LOADING OF 5/8-INCH CONCRETE ANCHORS

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INTRODUCTION

A series of static and dynamic tests were performed on 5/8-inch diameter expansion-type concrete anchors (Table 1 and Figure 1), utilizing equipment and services at the Structural Engineering Laboratory, University of California, Berkeley (UCB). This research project was performed under University of California Service to Industry Contract ES 7218. Anchors of the type tested are used in large numbers by P G and E construction crews and contractors for installation of equipment, such as ladders, pipes, cable trays, etc. Current design load values for the anchors are based on the application of safety factors to pullout and shear capacities, as determined by certified static load tests found in the manufacturer's literature. The purpose of the test performed at UCB was to determine the structural reponse and ability to resist pullout of various types of commercially available expansion-type anchors when subjected to static and dynamic loading, thus determining any additional safety factor to be applied to anchors used in cases of vibratory or seismic loading. Comparisons of the results of the test program for specimens within each bolt type indicated that the average value of the dynamic pullout load was within ± 15 percent of the average static pullout value. Test results indicated that for each specimen the degree of static pullout[1] at 75 percent of the average pullout load was comparable to the degree of dynamically induced pullout after sinusoidally loading the specimen from 500 pounds to 75 percent of the average pullout load, for a total of approximately 4800 cycles. This report contains tabular and graphical representations of both the static and dynamic tests of each anchor bolt type (Figure 2 and Table 3).

[1]The degree of pullout is defined as the withdrawal of the anchor from the concrete anchorage.

TEST PROGRAM AND PROCEDURES

Test Setup

Static and dynamic tests were performed on the following six anchor types (see Figure 1):

1. Kwik, 5/8-inch-diameter, wedge-type anchor, manufactured by McColloch Industries, Minneapolis, Minnesota.

2. Phillips Red Head, 5/8-inch, wedge-type anchor, manufactured by Phillips Drill Company, Michigan City, Indiana.

3. Phillips Red Head, 5/8-inch-diameter, self-drill flush-shell anchor, manufactured by Phillips Drill Company.

4. Phillips Red Head, 5/8-inch-diameter, sleeve-type anchor with 1/2-inch diameter threaded stud, manufactured by Phillips Drill Company.

5. Molly Para bolt, 5/8-inch-diameter, wedge-type anchor bolt, manufactured by USM Corporation, Temple, Pennsylvania.

6. Wej-It, 5/8-inch-diameter, wedge-type anchor bolt, manufactured by Wej-It Expansion Products, Incorporated, Broomfield, Colorado.

The anchors were set in precast concrete cylinders 14 inches in diameter and 12 inches in length (Figure 3). Twenty-three specimens had a reinforcing steel cage made up of No. 4 deformed bars cast into the cylinders. Eleven specimens were nonreinforced. The compressive strength of the concrete was approximately 3000 psi at loading, see Figure 4.

In the reinforced specimens, a 7.8-inch-diameter threaded rod was welded to the cage and projected from the lower end of the specimen. The test anchors were installed on the top face of each specimen in a manner specified by the anchor manufacturer. In all cases, the anchors were 5/8-inch-diameter.

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In the nonreinforced specimens, a 7/8-inch-diameter Phillips Red Head self-drive anchor was installed in the lower section of the specimen.

The testing program was designed to simulate, as closely as possible, job conditions ordinarily encountered in construction, carefully avoiding the use of any material, alignment jigs, or other installation method that would appear special, in order to establish conservative values for the anchors when subjected to diverse application in structural design and construction.

In all cases, the anchors were aligned with the bottom rod; however, in several specimens some minor eccentricity in load was noted. This varied from a very negligible amount to a maximum of approximately 1/2 inch. In the case of the wedge-type anchors, which required tightening of the retaining nut to set, the range of the torque applied was from 50 to 60 foot pounds.

Test Equipment

Tests were conducted using the 500 kip MTS Dynamic Test Frame and related instrumentation and control equipment located in Davis Hall, University of California, Berkeley Campus (Figures 5 and 6).

Test Arrangement and Loading Sequence

The specimens were installed in the test frame, as shown on Figures 7 and 8. Dial gauges were mounted opposite to each other on the top face of the specimen in order to measure the relative movement of the anchor and the concrete cylinder (Figure 9). An XY recorder (see Appendix A) was used to measure the overall displacement of the ram versus the applied load.

During the static load tests, each specimen was slowly loaded until failure occurred. During dynamic load tests, the initial maximum load applied was 75 percent of the average of the static pullout loads; or, should this be larger than one of the static loadings, then 95 percent of the smallest static loads was applied as the maximum initial dynamic load (Table 2). Table 2 outlines the applied dynamic load frequency and magnitude sequence used. The specimen was sinusoidally cycled between the initial maximum load and 500 pounds until failure occured or until the total number of load cycles had reached 3600 (Figures 10, 11, and 12). If pullout was not reached, the maximum load was then increased by 500 pounds and the specimen cycled at 5 Hz for an additional 300 cycles between this new maximum load and the minimum 500-pound load. The loads were increased in this manner, as noted in Table 2, in 500-pound increments, with the minimum load remaining at 500 pounds until failure occurred.

Under dynamic loading, it was noted that the average upper maximum pullout load for a particular anchor type was about 3 percent lower than that of the statically tested anchors of the same type.

TEST RESULTS

Static and dynamic test results are tabulated in Table 3, with brief comments given as to the type of failure.

Tables 4 through 15 give the degree of pullout for each of the anchors tested. During dynamic testing, the dial gauges were read at the maximum loads and at the mean load values.

The XY plots (load vs. overall degree of pullout) are attached as an appendix and are grouped according to the type of anchor with the test number as the key to correlating with the tabulated results.

DISCUSSION AND CONCLUSIONS

The ability of each anchor type to resist both static and dynamic pullout is related to the strength of the concrete into which it is embedded. Therefore, the compressive and tensile strengths of the concrete used in the test specimens are defined over each test period in Figure 3. The average strength, at the time of testing, was 3150 for all reinforced specimens and 3500 for all nonreinforced specimens.

Depth of embedment in the concrete was also a determining factor in the performance of the anchors. With greater depth of embedment, the anchor will be less subject to concrete failure because of a larger shear zone. In order to provide sufficient threads to anchor the actuating heads of the testing machine, the anchors were set so that the full length of the threaded anchor protruded above the concrete specimen surface. The Phillips self-drill anchor was set with its top flush to the concrete surface, while the Phillips sleeve anchor was set with the top of the sleeve at the concrete surface, as per manufacturer's instructions. To be consistent, the remaining anchors were set with the bottom stud thread at the concrete surface, resulting in embedment depths from 3 inches to 3-3/8 inches.

The average static pullout loads for each anchor type varied from 6350 pounds for the Kwik anchor to 11,170 pounds for the Phillips Red Head wedge anchor. The average dynamic pullout loads (at approximately 4800 cycles)

ranged from 7435 pounds for the Kwik anchor to 10,150 pounds for the Red Head wedge anchor. Complete results are found in Table 3.

Generally, the degree of anchor pullout (withdrawal) resulting from the dynamic cyclic loading (at 3600 cycles) accounted for less than 20 percent of the total measured anchor withdrawal (withdrawal due to both static and dynamic loading) obtained during specimen loading.

Since degree of pullout is an important point that is seldom covered in manufacturer's literature, it is recommended that decisions to use any anchor type be based on its degree of pullout (as defined in the previously mentioned tables), as well as its pullout load.

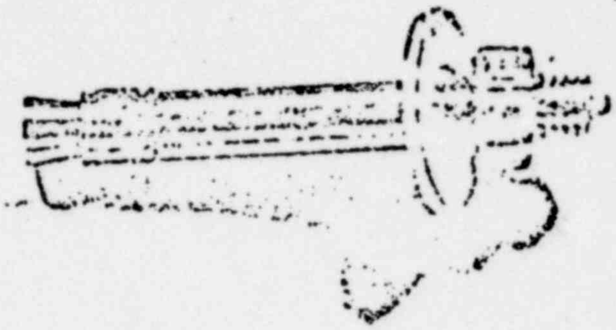
TABLE 1

Types of Anchors Tested

Anchor Type	Manufacturer	Number of Specimens: Reinforced, Static	Reinforced, Dynamic	Non-Reinforced, Static	Non-Reinforced, Dynamic
Kwik - 5/8" dia.	McCulloch Industries	2	2	1	1
Red Head Wedge 5/8" dia.	Phillips Drill Co.	2	1	1	1
Red Head Self Drill 5/8" dia. Flush Shell	Phillips Drill Co.	2	2	1	1
Phillips Sleeve 5/8" dia. Anchor - 1/2" dia. stud	Phillips Drill Co.	2	2	1	1
Parabolt 5/8" dia.	USM Corporation The Molly Company	2	2	1	1
Wej-It 5/8" dia. x 4-1/2"	Wej-It Expansion Products, Inc.	2	2		1

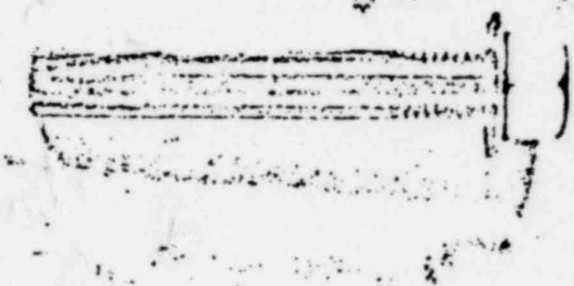
Concrete Anchor Types

Molly, "Parabolt", 5/8" x 5", PB 58-S



McCullock, "Kwik", 5/8" x 4 1/2", 58-412

WEJ-IT, 5/8" x 4 1/2", 5844



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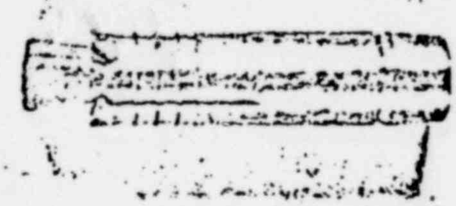
Phillips (Redhead), 5/8", Self Drill Anchor, S-58



Phillips (Redhead), 5/8" x 5" Wedge Anchor, WS 5850

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Phillips (Redhead), 5/8" x 4 1/4" Sleeve Anchor, HN 5842

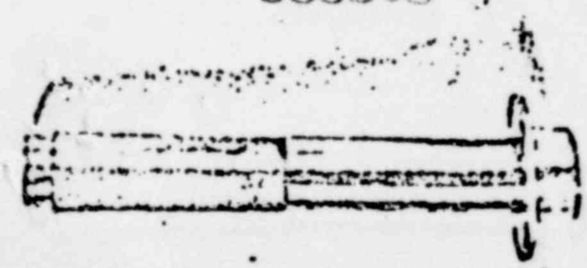

TABLE 2

Dynamic Load Sequence

POOR ORIGINAL

Test Period	Cycles/Second	Duration, Sec.	Cumulative Cycles
1	5	30	150
2	10	30	450
3	15	30	900
4	5	30	1050
5	10	30	1350
6	15	30	1800
7	5	60	2100
8	10	60	2700
9	15	60	3600
Increase Load by 500 lbs 10	5	60	3900
Increase Load by 500 lbs 11	5	60	4200
Increase Load by 500 lbs 12	5	60	4500
Increase Load by 500 lbs 13	5	60	4800
Increase Load by 500 lbs 14	5	60	5100

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TABLE 3

Results of Concrete Anchor Test Program

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	Test No.	Anchor Type	Size Inches	Torque Ft.Lb.	Loading Type	Failure Load Lbs.	Comments
	1	Kwik	5/8	60	Static	7400	Bolt Pull Out
	2	Kwik	5/8	60	Static	5850	Bolt Pull Out
	3	Wej-It	5/8	Finger Tight	Static	6300	Bolt Pull Out
	4	Wej-It	5/8	Slightly Torqued	Static	7950	Bolt Pull Out
Static	5	Molly Parabolt	5/8	50	Static	9850	Concrete Failure
	6	Molly Parabolt	5/8	50	Static	9700	Concrete Failure
Dynamic	7	Molly Parabolt	5/8	50	Dynamic	8400	Concrete Failure at 3900 Cycles
	8	Molly Parabolt	5/8	60	Dynamic	8900	Concrete Failure at 4801 Cycles
	9	Wej-It	5/8	Hand Tight	Dynamic	7300	Bolt Pull Out at 4501 Cycles
	10	Wej-It	5/8	Hand Tight	Dynamic	6860	Bolt Pull Out at 4502 Cycles
	11	Kwik	5/8	60	Dynamic	7200	Bolt Pull Out at 4502 Cycles
	12	Kwik	5/8	60	Dynamic	7400	Bolt Pull Out at 4802 Cycles
	13	Phillips Red Head Wedge	5/8	50	Static	13000	Bolt Pull Out
	14	Phillips Red Head Wedge	5/8	50	Static	10500	Bolt Pull Out
	15	Red Head Self Drive Flush Shell	5/8	Driven	Static	9000	Concrete Failure
	16	Red Head Self Drive Flush Shell	5/8	Driven	Static	9900	Concrete Failure
Reinforced	17	Phillips Sleeve 1/2" Stud	5/8	50	Static	10000	Bolt Pull Out
Static	18	Phillips Sleeve 1/2" Stud	5/8	50	Static	10400	Stud Tension Failure

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TABLE 3-contd

Results of Concrete Anchor Test Program

	Test No.	Anchor Type		Size Inches	Torque Ft.Lb.	Loading Type	Failure Load Lbs.	Comments
Reinforced	19	Phillips Sleeve 1/2" Stud	Dynamic	5/8	50	Dynamic	10100	Concrete Failure at 4802 Cycles
Reinforced	20	Phillips Sleeve 1/2" Stud	Dynamic	5/8	50	Dynamic	11100	Concrete Failure at 5402 Cycles
Reinforced	21	Phillips Red Head Self Drive Flush Shell	Dynamic	5/8	Driven	Dynamic	9600	Concrete Failure at 4928 Cycles
Reinforced	22	Phillips Red Head Self Drive Flush Shell	Dynamic	5/8	Driven	Dynamic	7100	Concrete Failure at 1980 Cycles
Reinforced	23	Phillips Red Head Wedge	Dynamic	5/8	50	Dynamic	8900	Concrete Failure at 3902 Cycles
Non-Reinforced	24	Phillips Red Head Wedge Non-Reinforced	Dynamic	5/8	50	Dynamic	11400	Concrete Failure at 5663 Cycles
Non-Reinforced	25	Phillips Red Head Wedge	Dynamic	5/8	50	Dynamic	10000	7/8" Flush Shell Pull Out
Non-Reinforced	26	Phillips Sleeve 1/2" Stud Non-Reinforced	Static	5/8	50	Static	4300	Bolt Pull Out
Non-Reinforced	27	Molly Parabolt Non-Reinforced	Static	5/8	50	Static	9500	Concrete Failure 7/8" Flush Slipping
Non-Reinforced	28	Kwik, Non-Reinforced	Static	5/8	50	Static	5800	Bolt Pull Out
Non-Reinforced	29	Phillips Red Head Self Drive Flush Shell Non-Reinforced	Static	5/8	Driven	Static	9400	Concrete Failure as Shell Pull Out
Non-Reinforced	30	Molly Parabolt Non-Reinforced	Dynamic	5/8	50	Dynamic	9800	Concrete Failure 4801 Cycles
Non-Reinforced	31	Kwik, Non-Reinforced	Dynamic	5/8	50	Dynamic	7700	Bolt Pull Out at 4802 Cycles
Non-Reinforced	32	Phillips Red Head Self Drive Flush Shell Non-Reinforced	Dynamic	5/8	Driven	Dynamic	7100	One Foot on Flush Shell Broke Off Bolt Pull Out at 220 Cycles

TABLE 3-contd

Results of Concrete Anchor Test Program

Test No.	Anchor Type		Size Inches	Torque Ft.Lb.	Loading Type	Failure Load Lbs.	Comments
33	Wej-It Non-Reinforced	Dynamic	5/8	Hand Tight	Dynamic	8800	Bolt Pull Out at 5702 Cycles
34	Phillips Sleeve 1/2" Stud Non-Reinforced	Dynamic	5/8	50	Dynamic	8100	Concrete Failure at 3601 Cycles

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TABLE 4

AVERAGE DIAL GAGE READINGS FOR KWIK ANCHORAGE - STATIC TEST

Load, Lbs.	Displacement, Inches		
	Test No. 1	Test No. 2	Test No. 28
0	0	0	0
1000	.004	.001	.006
2000	.086	.037	.011
3000	.148	.135	.080
4000	.198	.196	.180
5000	.264	.257	.254
6000	.330	(5850 lbs) Failure bolt pulled out	Failure (un-documented)
7000	.420		
8000	(7400 lbs) Failure bolt pulled out		

Note: 5/8" KWIK-Bolt

Nos. 1 and 2 Reinforced.

Nos. 28 Non-Reinforced.

TABLE 5

AVERAGE DIAL GAGE READINGS FOR KWIK ANCHORAGE - DYNAMIC TEST

Load, Lbs.	Cycles, Total	Displacement, Inches		
		Test No. 11	Test No. 12	Test No. 31
0	0	0	0	0
5200	0	.212	.205	.264
2850	0	.223	.210	.264
2850	4	.240	.215	-
2850	150	.247	.220	.280
2850	300	.244	.228	.284
2850	900	.250	.231	.286
2850	1050	.254	.235	.290
2850	1350	.258	.238	.292
2850	1800	.260	.240	.298
2850	2100	.264	.243	.301
2850	2700	.264	.245	.302
2850	3600	.268	.247	.302
5700		.278	.258	.314
3100		.280	.260	.310
3100	3900	.287	.268	.314
6200		.304	.291	.338
3350		.308	.302	.328
3350	4200	.325	.318	.339
6700		.372	.344	.362
3600		.366	.348	.360
3600	4500	.400	.370	.378
7200		Failure	.405	.404
3850			.407	.404
3850	4800		.465	.436
7400			Failure	Failure

Note: 5/8" KWIK-Bolt 4" Depth

Nos. 11 and 12 Reinforced.

No. 31 Non-reinforced.

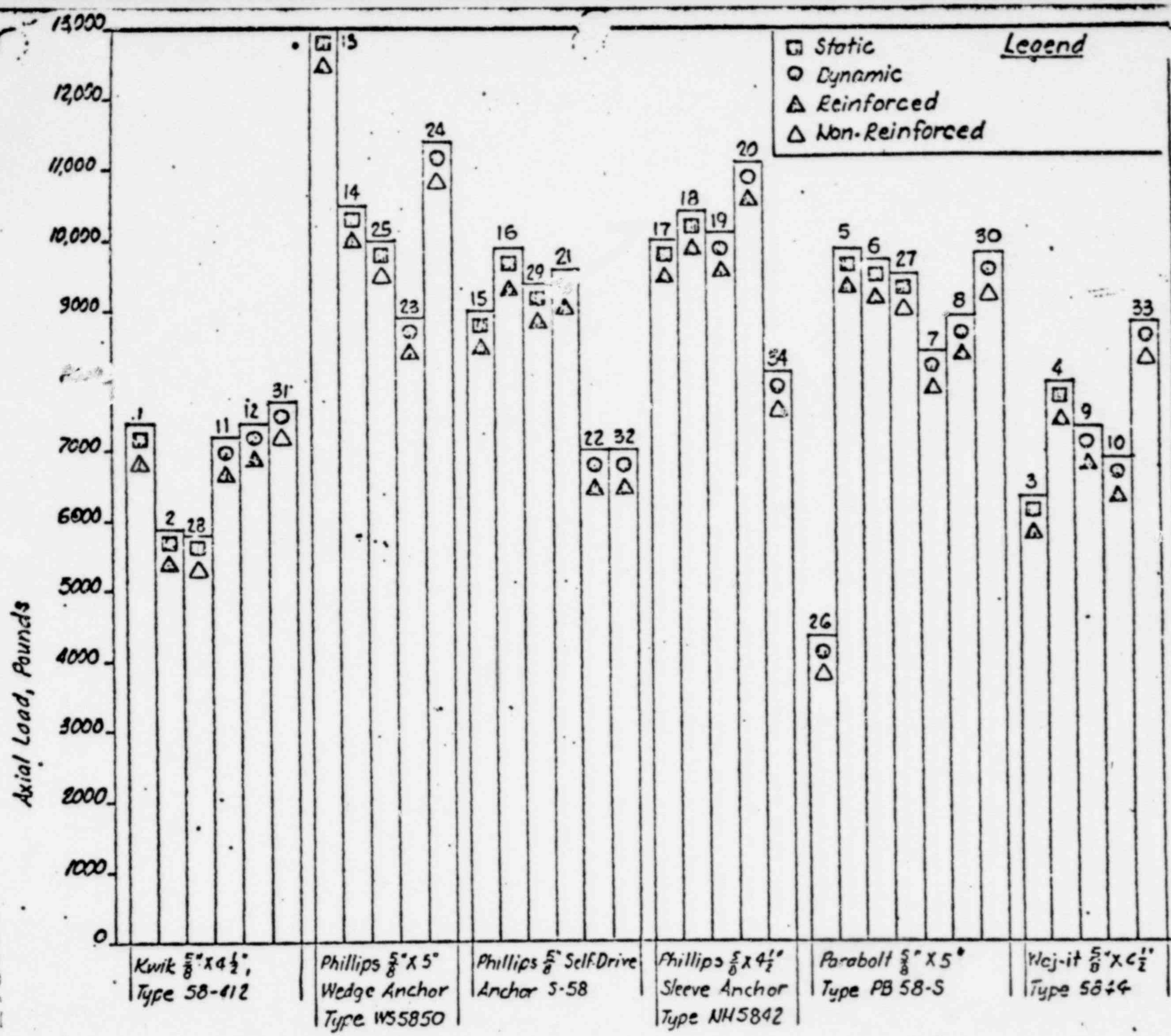

Figure 2

Maximum Pullout Resistance of Various Concrete Anchor Types under Static and Dynamic Loading

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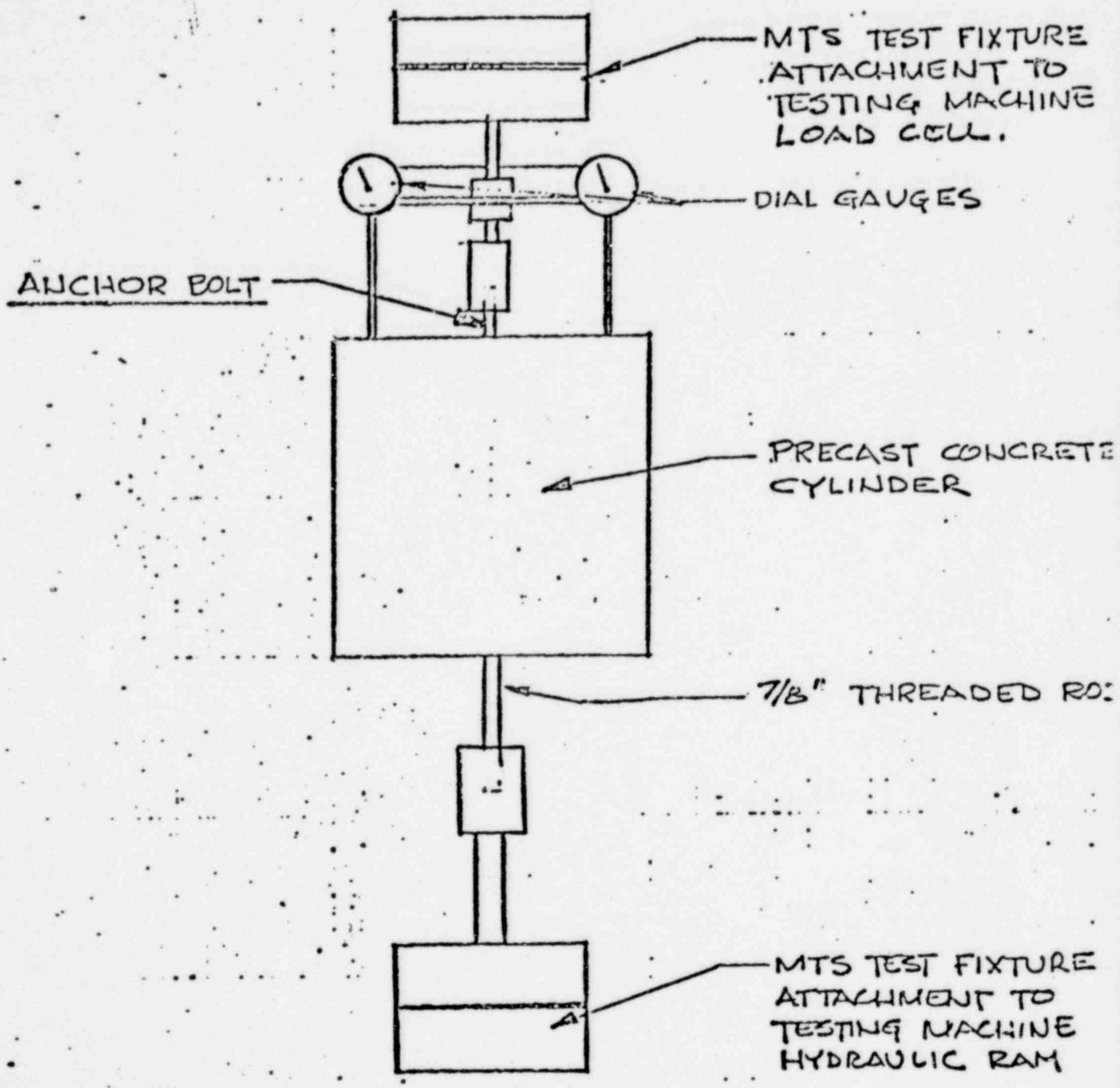
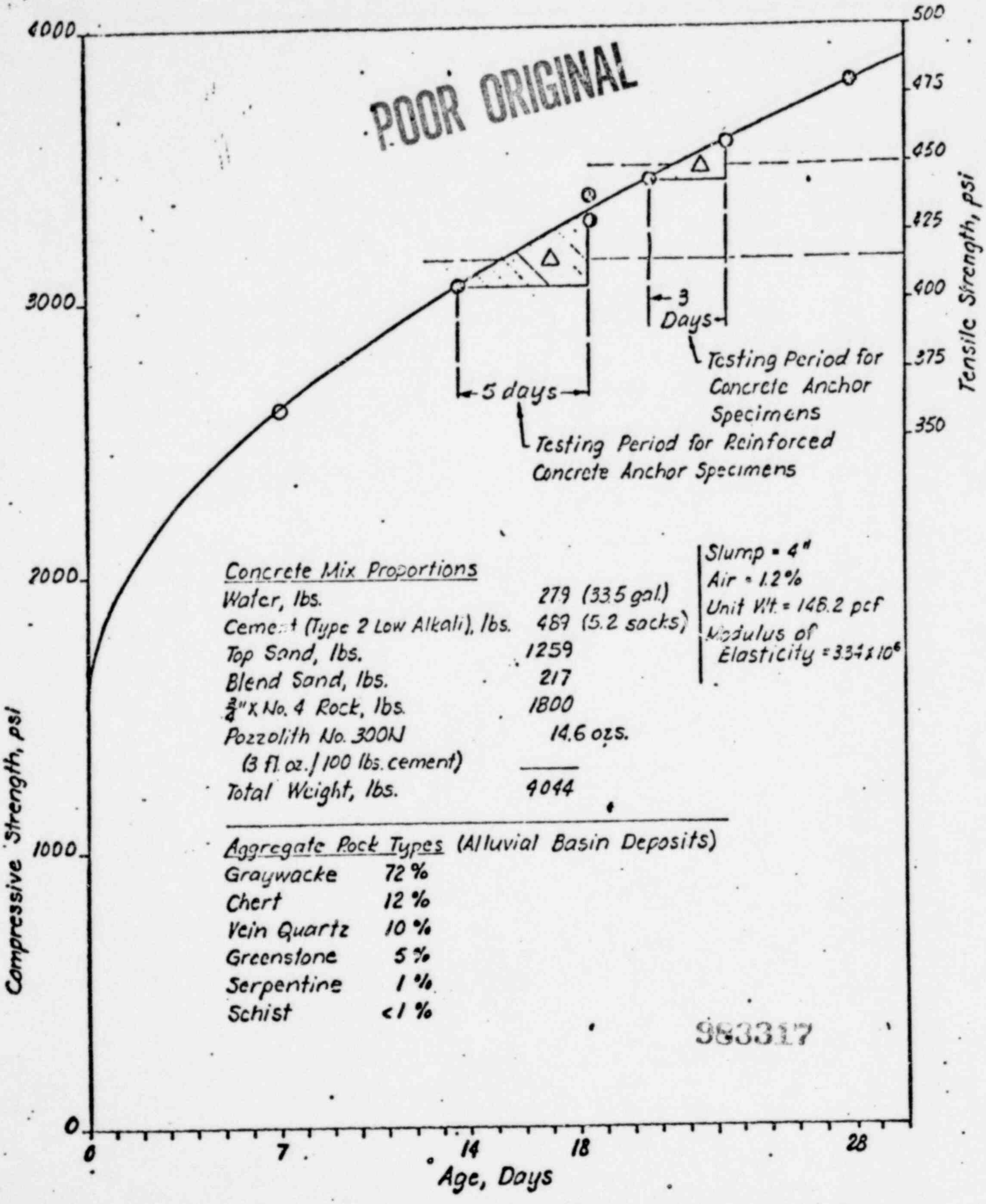


FIG.3 - TEST ARRANGEMENT



Concrete Anchor Tests - Age/Strength Relationship for Concrete Specimens during Test Periods

Figure 4

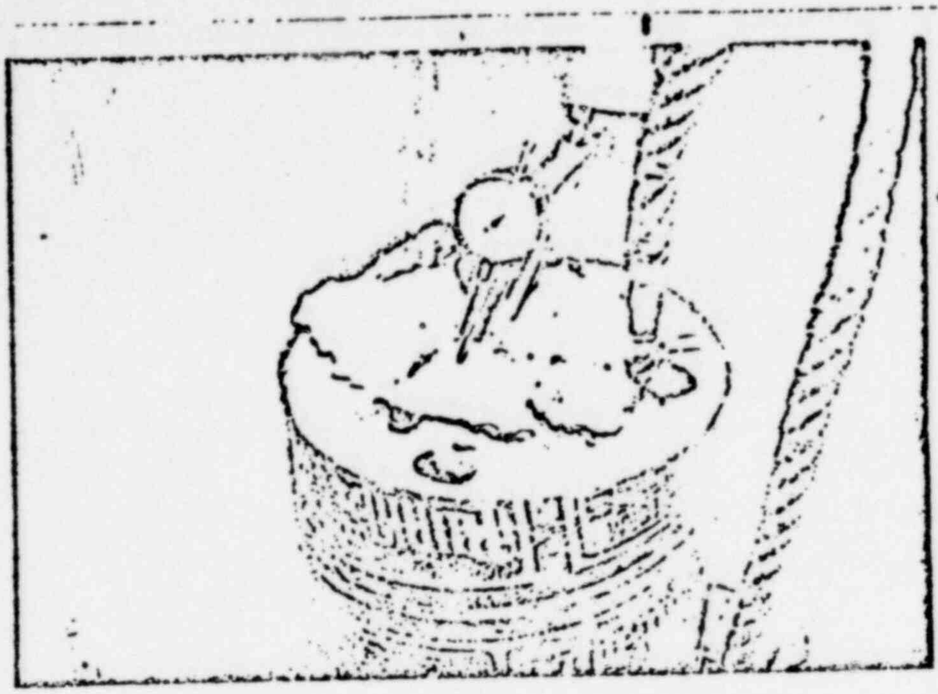


Figure 9. View showing anchor pullout and tensile failure of concrete during maximum loading.

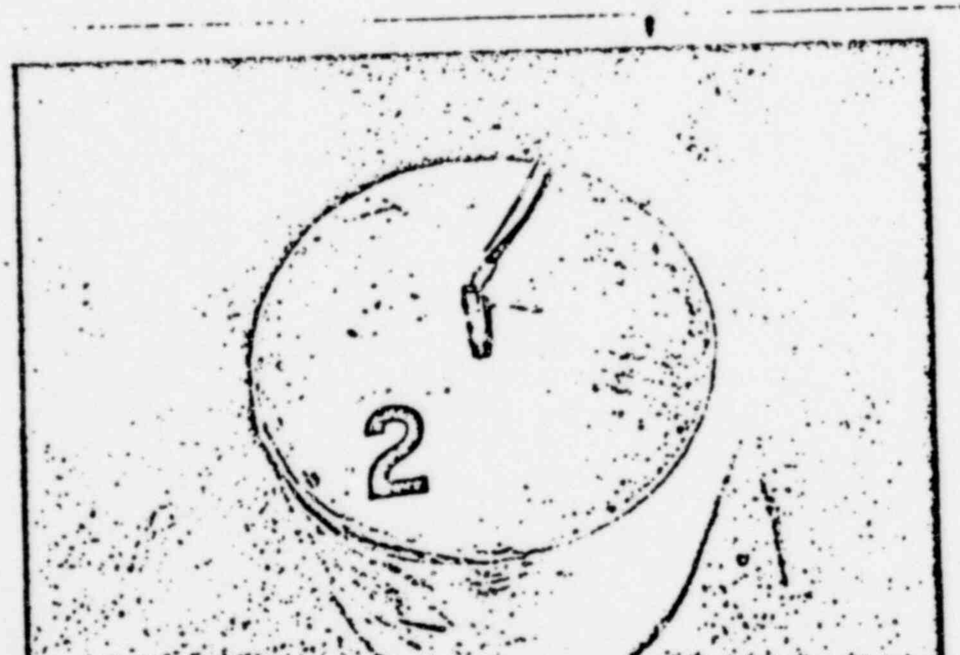


Figure 10. View of typical ancher pullout-type failure during loading.

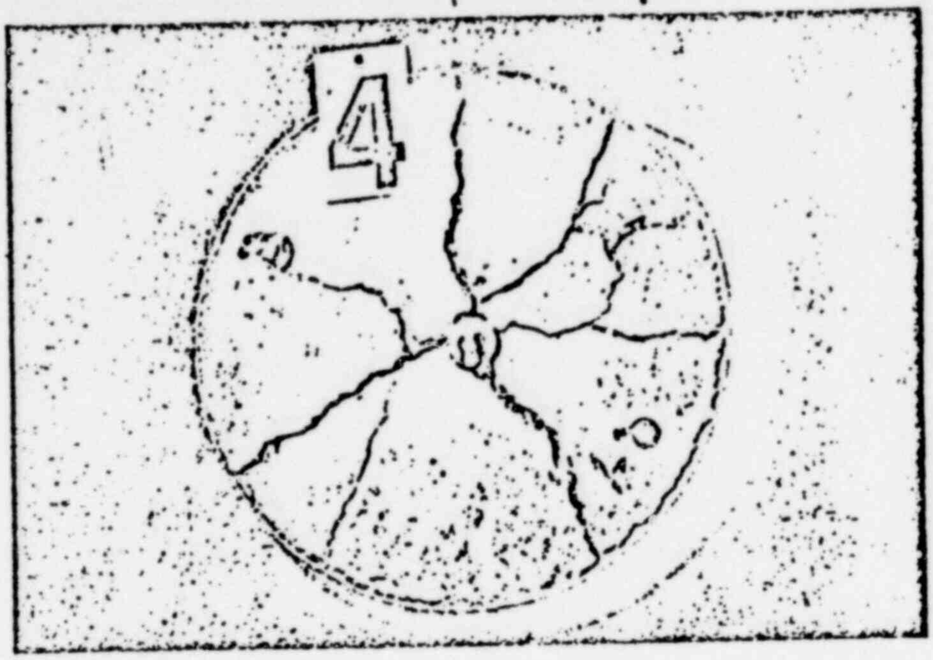


Figure 11. Typical failure pattern obtained during static test of Phillips Sleeve Anchor embedded in reinforced concrete specimen.

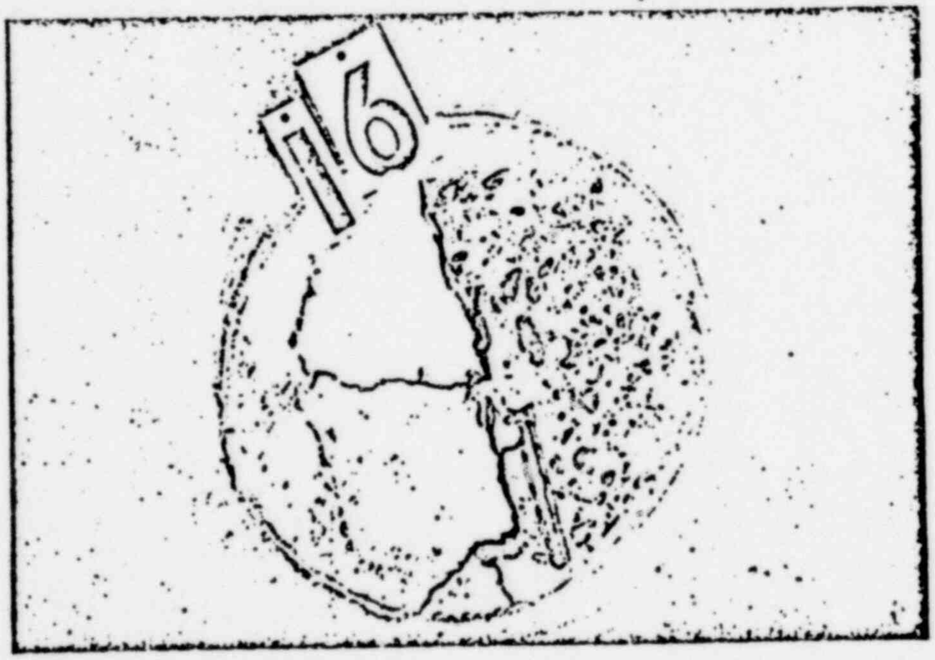


Figure 12. View of spalled concrete showing the extent of the cone-type failure and aggregate distribution in exposed concrete surface. (Static test of Molly Parabolt reinforced concrete specimen.)

FIGURE 2.15- 3

POOR ORIGINAL

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☑ Document

Title IE Bulletin 79-02 Revision No. 1 Evaluation
Report # AECM-79/93

Review Request Letter No.: PMI-___/___ Dated: ____________

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Part II - To be completed by Reviewer(s)

Approved by: W. E. Edge for T. E. Reaves, Jr. Date: 8/15/79
Manager of Quality Assurance

Reviewer's Signature W. E. Edge Date: 8/15/79

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